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BULLETIN No. 14. V. P. P.—57.

U. S. DEPARTMENT OF AGRICULTURE.

DIVISION OF VEGETABLE PHYSIOLOGY AND PATHOLOGY.

THE BERMUDA LILY DISEASE:

A PRELIMINARY REPORT OF INVESTIGATIONS.

BY

ALBERT F. WOODS,
ASSISTANT CHIEF, DIVISION OF VEGETABLE PHYSIOLOGY AND PATHOLOGY.

WASHINGTON:
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LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
DIVISION OF VEGETABLE PHYSIOLOGY AND PATHOLOGY,
Washington, D. C., July 7, 1897.

SIR: I have the honor to transmit herewith, for publication as Bulletin No. 14 of this Division, a preliminary report on a disease affecting the Bermuda or Easter lily—a subject of considerable importance to the florists of the country.

Within recent years the forcing of this lily has become an important industry in the United States. As is well known, the bulbs are grown almost exclusively in Bermuda, where they mature in July, and are then shipped to this country to be forced the following fall, winter, and spring. During the past five or six years a disease, which is apparently becoming more destructive each season, has seriously interfered with the profitable growth of the crop. An investigation of the trouble was commenced two or three years ago by this Division and has been continued from time to time in connection with other maladies affecting plants under glass. During the progress of the investigation bulbs were obtained from various sources and were grown in numerous ways, the object being to obtain direct information in regard to their behavior under different cultural conditions. The work is not yet complete, but it is believed sufficient has been accomplished to warrant the preliminary report following. This has been prepared by Mr. Albert F. Woods, assistant chief of the Division, who carried on the investigation and planned and conducted the experiments in growing the bulbs.

Respectfully,

B. T. GALLOWAY,
Chief of Division.

Hon. JAMES WILSON,
Secretary of Agriculture.

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THE BERMUDA LILY DISEASE: A PRELIMINARY REPORT OF INVESTIGATIONS.

CHARACTERISTICS OF THE LILY DISEASE.

The lily disease is characterized by the spotting and distortion of the leaves and usually of the flowers, spotting of the scales of the bulbs, and generally the stunting of the plants. In severe cases the first leaves as they appear above ground are more or less distorted, and are marked with small, yellowish white, often longitudinal, and more or less shrunken spots or streaks. These increase slightly in size, continue to grow paler, and finally collapse, dry out, and turn light brown. Each succeeding whorl of leaves becomes similarly affected, and finally the flowers show the shrunken spots and the distortions. Sometimes badly affected plants are apparently strong, vigorous growers, as shown in fig. 1, but usually they produce only one or two small, distorted flowers.

It often happens that the leaves of a diseased plant are not all affected in the same degree. Several of the lower, middle, or top whorls may be badly diseased, while the others may be comparatively healthy; occasionally the leaves on one side of the stem are much more spotted and distorted than those on the other; or, as is often the case, one side of a leaf will be diseased and the other remain comparatively healthy. Again, the tissues of the stem at the point of attachment of diseased leaves often collapse and turn brown in much the same way as do the tissues of the leaf.

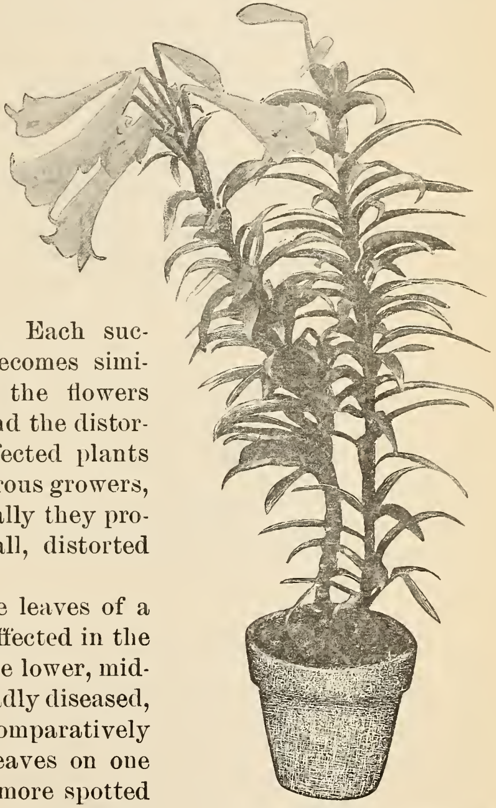

FIG. 1.—A diseased lily showing distorted and spotted flowers.

When the flowers become spotted, the plants are unsalable, no matter whether the leaves are badly diseased or not, and are therefore a complete loss to the grower. When the flowers and a few of the upper whorls of leaves escape, the plants are usually disposed of for decorative purposes where only the flowers are required. The popular demand, however, is for perfect flowers and perfect leaves, as even a slight disfigurement will cut down the market value of the plant.

PREVALENCE OF THE DISEASE AND ITS DESTRUCTIVENESS IN THIS COUNTRY.

The disease is about equally severe on *Lilium longiflorum* and *L. harrisii* and has also been observed on *L. aurantum* and *L. candidum*. In Bermuda it occurs in the fields, attacking the plants when partly grown. Frequently the lower part of the plant remains healthy, while the upper portions become diseased. The trouble is also, without doubt, prevalent in the Netherlands, France, and Japan, for the writer has seen plants from bulbs grown in these countries as badly diseased as those from bulbs grown in Bermuda. In this country it appears wherever the bulbs are forced, and from a commercial standpoint destroys from 20 to 60 per cent of the entire crop. This estimate does not include the bulbs that fail to grow or that make stunted, worthless plants. The loss from this source is seldom less than 5 per cent, and often exceeds 20 and even 30 per cent.

THEORIES AS TO THE CAUSE OF THE DISEASE.

Many theories have been advanced as to the cause of the lily disease and in our investigations these have all been studied as far as possible. The writer was, however, unable to obtain bulbs from which flower stems had been cut or which were known to be immature, hence our conclusions relative to these points are only general, having been based on the second growth of bulbs which were developed by forced plants.

WORN-OUT SOIL.

Some growers attribute the trouble to exhaustion of food in the soil in which the bulbs are grown. That this is not the case, however, is at once apparent from the fact that it often appears on new land never before planted to lilies and on lands highly fertilized, and from the further fact that healthy plants are frequently grown on old soils which have been cropped to lilies for several years. Another argument against this theory is the sporadic distribution of the diseased plants in a field.

PREMATURE REMOVAL OF FLOWERS AND STEMS.

It has been the custom of some growers in Bermuda to cut prematurely many of the best flowers, including from one-half to two-thirds of the stem, in order to sell them. This practice is believed by many to result in diseased plants, as in this way the bulbs are deprived of a large part of their nourishment at the very time when they need it most.

PREMATURE HARVESTING.

Owing to the demand in this country for bulbs to force for the Christmas and New Year's trade, many growers in Bermuda formerly dug their bulbs before they were properly matured and rested. The general observation of forcers was that plants grown from such bulbs were weaker and much more subject to the disease than those from well-ripened and rested bulbs.

SELECTION OF STOCK FOR PROPAGATION.

Some of those familiar with bulb growing in Bermuda claim that the selection of stock for propagation does not receive sufficient attention, bulbs of poor quality often being used for this purpose. There can be little doubt that this carelessness has led to great variation in quality and vigor of the bulbs, and consequently in the plants grown from them.

TREATMENT DURING FORCING.

Some believe that bad treatment during forcing has much to do in bringing on the disease. By bad treatment is usually meant a lack of care in watering, controlling temperature, etc.—in short, a failure to supply the most favorable conditions for the growth of the plant.

INSECTS.

Finally many of the Bermuda growers think that the trouble is due to "an insect" which feeds on the scales and roots of the bulb.

EVIDENCES AS TO THE CAUSES INFLUENCING THE LILY DISEASE.

Early in the progress of the work on this disease it became evident that the trouble could not be assigned to any one factor or set of factors. This is true in many maladies, but in some the complications are not so great as in others.

NATURAL OR INHERENT VIGOR OF THE BULBS.

It is a well-known fact that in any given lot of bulbs, all of which have been carefully selected as to size and general quality and given exactly the same treatment in forcing, there is always a great difference in the rapidity and vigor of growth and time of flowering. In our experiments certain individuals were observed which were very sensitive to changes in temperature and variations in moisture content of the soil and air. They were easily checked by a low temperature and stimulated to too rapid growth by a high one, their roots were quickly injured by becoming a little too wet or too dry, and the leaves also suffered from these causes. Other plants subjected to the same changes were not injured. The second growth from the bulbs and scales behaved in the same manner as the parent plants, that is. the plants were sensitive or resistant to conditions of environment in a corresponding degree.

It was found that any plant could be weakened and stunted if the unfavorable variations were permitted to become great enough. Many comparatively healthy plants were brought into this condition by keeping the soil about the roots quite wet. so that they were partially asphyxiated. The plants so treated made a stunted, weak growth, the lower leaves gradually drying up.

Similar results were also produced by severe root pruning during growth. Where certain roots were injured in this process it was found that the parts of the top most directly fed by these became weak. light-colored, and more or less stunted. In the study of a large number of diseased plants we have found that a weakened top growth is usually accompanied by a correspondingly weakened root growth (fig. 2). This is not always apparent when the bulb is simply removed from the pot. for in such cases the roots of even badly diseased plants often appear to be quite healthy, but when washed out and separated many are found to be in various stages of decay. It was also seen that a healthy bulb could be made to produce a diseased plant by careless or improper handling.

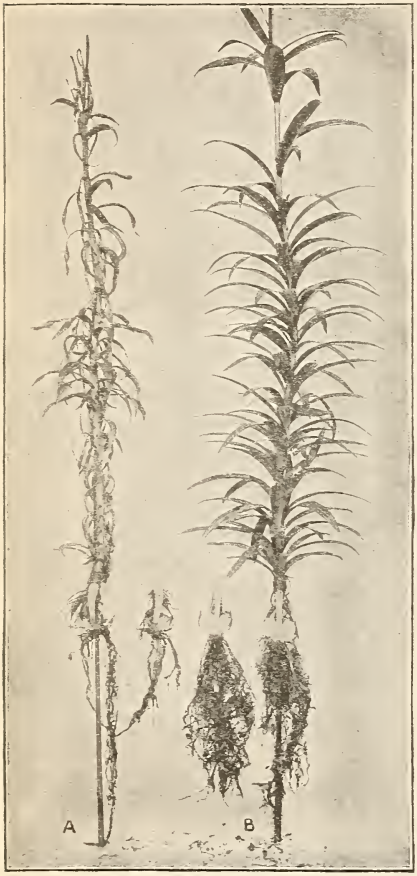

Fig. 2.—Diseased and healthy plants showing comparative development of roots and tops: *a*, diseased plant; *b*, healthy plant.

INSECT AND FUNGOUS PARASITES.

Besides being more easily injured by unfavorable cultural conditions, the naturally weak plants were found to be more subject to the attacks of certain parasitic organisms. Probably the most common and destructive insect enemy of the roots and bulbs is the bulb mite (*Rhizoglyphus echinops*), a white, sluggish insect, with brown legs (fig. 3). When mature the insect is about the size of a mustard seed, but in the early stages is scarcely visible to the naked eye. They are found in immense numbers in the decaying portions of the bulbs and roots and also bore their way into perfectly healthy tissues. No root is immune from their attacks, but they are most destructive at the base of the bulb, which they often completely honeycomb (fig. 4). They do not stop here, however, but follow the roots up into the bulb, injuring them to such an extent as to render them useless to the plant. In our colonization experiments, roots were often found to be worthless in less than a week after being attacked by the mites.

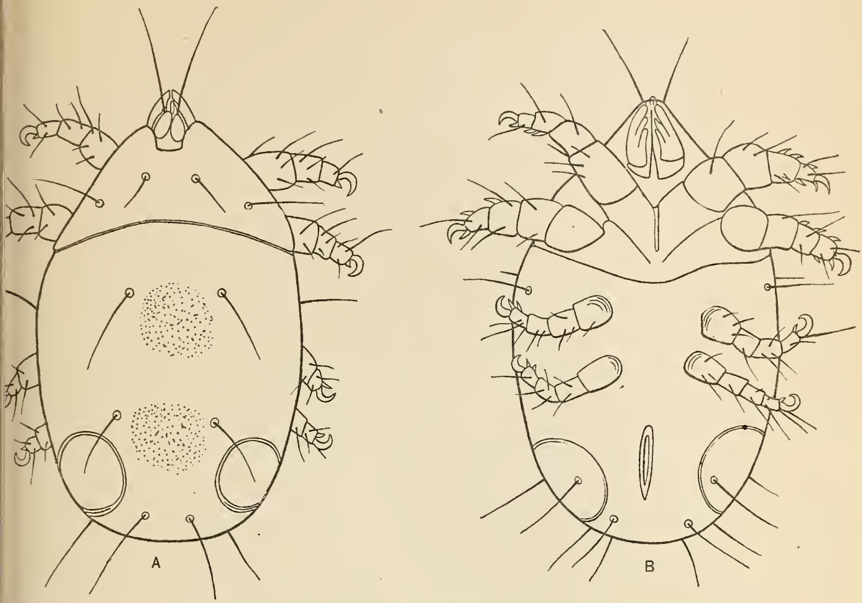

Fig. 3.—Upper and under view of a mite: *a*, upper view; *b*, under view (magnified fifty times).

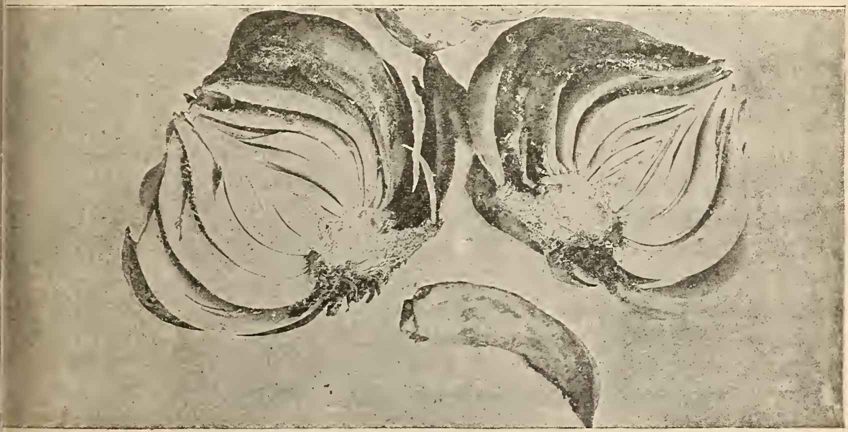

Fig. 4.—Diseased bulb showing work of mites.

The burrows of the mite open the way for several fungi and bacteria, which under favorable conditions greatly aid in the destruction of the tissues attacked. One of the most important of these is Oospora sp., a minute fungus closely related to the one producing scab of potatoes. It is most harmful on roots injured by mites, but is not confined to these. Roots attacked by this fungus become yellow, greatly branched, and stunted. It works mainly in the outer tissues and root tips, and although it does not itself cause the rotting, it opens the way for the fungi and bacteria which do. When injected into the young leaves or flower buds, it causes almost complete cessation of growth in the parts affected, although they still remain green and are not killed. The lower epidermis over the inoculated parts of the leaves turns a yellowish brown. Several other organisms also were found which produce this yellowing of the lower epidermis, but these did not cause the stunting. None of them, however, were able to attack the leaf unless injected into the intercellular spaces. Injection in this way occurs frequently in the process of syringing or wetting the foliage. When water strikes the lower surface of a lily leaf with any considerable force, it passes through the stomata into the intercellular spaces, where it often remains for twenty-four to forty-eight hours and causes water-logging of the tissues. In such cases the cells become greatly injured and partially asphyxiated, the spores of parasitic fungi or bacteria introduced with the water develop, and the affected tissues finally collapse and produce a spot. That these organisms, however, are not present in the tissues of the spotted areas of most of the diseased leaves and flowers has been conclusively shown by microscopic and cultural study. How much injury is due to water-logging has not been definitely determined, but our observations so far indicate that it is considerable, especially in naturally weak plants.

The most destructive insect enemy of the leaves and flowers of the lily is the so called green fly, a species of aphis. As shown by colonization experiments, they develop rapidly on certain plants and can hardly be made to live at all on others. As in the case of mites, the plants most susceptible to the attacks of the aphides are almost invariably those which are naturally weak or which have been weakened through some unfavorable condition. The aphides crawl in between the young leaves at the growing point, where they are practically free from smoke during the fumigation of the plants. Here they feed, multiply, and spread to the older leaves between fumigating periods. Usually the insects do not puncture the epidermis, but push their sucking apparatus through the stomata into the softer tissues underneath, consuming their contents, and probably also injecting some substance into the wound which acts as an irritant. The plants most favorable to the aphides suffer quickest from their work. When a young leaf or flower bud of such a plant is punctured, the injured tissues do not grow normally, but become œdemic, that is, the cells slowly lose their chlorophyll and become thin-walled and more or less transparent. After three or four weeks these punctured areas collapse and produce a spot like that characteristic of the lily disease, and in consequence of the stunted condition of the punctured areas the leaves and flowers become distorted.

When the secondary bulbs from susceptible plants start to grow, the young growth is usually infected. The explanation for this is that the plants are not only favorable to the insects, but the latter are present in the bulb between the scales ready to attack the new growth as it appears. The writer has found that the insects pass the winter in this way in bulbs planted out of doors.

PREVENTIVE MEASURES.

HEALTHY STOCK.

From what has been said, it is evident that preventive measures against the lily disease must begin with careful attention to the culture of the bulb in the field and with rigid selection of bulbs for use or sale. Every plant which shows the disease should be dug up and destroyed. Only bulbs of strong, healthy plants should be used for propagating purposes. Scales which are spotted should not be used. A second selection should be made when the plants from the scales are transferred to the field, and all those showing spotted leaves or mite-infested roots or bulbs should be destroyed. A third selection should be made in marketing, all badly spotted bulbs and those having decayed bases being destroyed. If this rigid selection were practiced by the growers in Bermuda, the quality of the bulbs received in this country would be far superior to what it is at present and the difficulties encountered in forcing would be greatly lessened.

As every scale and every bulb will produce a plant essentially like the parent, and plants grown from weak stock are naturally more susceptible to the disease, it is very important that only bulbs of strong, healthy plants, free from all undesirable qualities, should be used for propagation.

Doubtless the reason for the disease being most common on bulbs grown on old soil lies in the fact that the soil on which the crop has been cultivated for a number of years becomes thoroughly infested with mites and other enemies. For this reason it is very important that some system of crop rotation be adopted in order to free the soil from these organisms. Clean, strong plants placed in soil free from mites will be likely to produce healthy bulbs, but diseased stock placed in such soil will produce diseased bulbs. The bulbs should be ripened with the stems on and should not be dug for market until fully matured and rested.

DISINFECTION.

As yet no treatment has been found which will effectually free infested bulbs without injuring them. In our experiments bulbs were soaked in sulphur solution for two to five hours, and while all the mites reached were killed, those protected by the tissues of the bulb escaped. When bulbs were soaked two hours in corrosive sublimate ($\frac{1}{1000}$ to $\frac{1}{2000}$) the mites were not all reached and the bulbs were injured. Soaking two hours in formalin ($\frac{1}{1000}$ to $\frac{1}{2000}$) was not effective and the bulbs were injured. Fumigating with hydrocyanic acid gas (one-tenth gram of 50 per cent KCN per cubic foot of space) for three hours was not effective, although all the mites reached by the gas were killed. It is probable that this gas can be used much stronger than it has yet been tried and may give better results. It is extremely important that the mites and aphides be kept off the plants from the start, for if they once get a foothold it is almost impossible to get rid of them without injuring the plants. The pots may be plunged in coarse coal ashes and the tops mulched with tobacco stems to keep down these pests. When smoking can not be resorted to, a liberal supply of tobacco stems or dust should be used.

AERATION.

The bulbs to be forced should be planted in well-drained, well-aerated soil, containing not more than one-fourth well-rotted organic manure. The roots, as well as the bulbs, require a large amount of oxygen and this they can not obtain if the soil is too wet. Great care should be exercised in watering to keep the water off the young foliage, for, as above stated, the latter is often injured by the water being injected into the intercellular spaces or remaining on the leaves for some time. The houses should be kept well ventilated in order to insure strong plants.

SELECTION OF FERTILIZERS.

In feeding, solutions of organic fertilizers, like cow, horse, or sheep manure, should be avoided if possible, as they have a tendency to clog the soil. Chemical fertilizers in weak solution will probably give superior results, although this question must be determined by more extensive experiment.

SUMMARY.

(1) The lily disease is characterized by the spotting and distortion of the leaves and flowers and usually the stunting of the plant.

(2) The disease is quite serious on *Lilium longiflorum* and *L. harrisii* and also attacks *L. auratum* and *L. candidum*. It is very prevalent in Bermuda; and in the United States where the bulbs are forced, it destroys from 20 to 60 per cent of the crop. It also doubtless occurs in Japan, France, and the Netherlands.

(3) There are many theories as to the cause of the lily disease, the principal ones being worn-out soil, premature removal of flowers and flower stems, premature harvesting of the bulbs, carelessness in the selection of stock for propagating purposes, bad treatment during forcing, and the work of insects.

(4) The work done shows that the disease is due to a combination of causes. In the first place the bulbs have become weakened through improper selection and improper propagation, and this weakening is further increased by the attacks of mites and certain fungi and bacteria. Bulbs which have been weakened in this way might regain their strength if the mites and fungi could be kept down, but those which are naturally weak can not be made strong. During the time plants are being forced they may also be weakened by overwatering and consequent asphyxiation of the roots, or by allowing the roots to become too dry and then overwatering. The foliage of such plants may be free from spots and distortions, but usually the leaves are badly diseased.

(5) The spotting and distortion of the foliage is often due to the direct attacks of several genera and species of aphides and of the young of the bulb mite, to the injection of water into the young leaves in watering or syringing, and to the presence of water between the young leaves of plants having soft foliage. The injuries from the attacks of organisms are always more severe on the susceptible or naturally weakened bulbs.

(6) The disease can not be cured or even prevented by adopting any single course of treatment. The fact that the bulbs have become more or less weakened by improper cultivation, selection, and propagation shows the importance of adopting rigid measures to improve the stock. Only the strong and vigorous plants should be used for propagation. Crop rotation should be practiced in order to prevent the increase of mites and injurious fungi. Leave the stems on the bulbs until ripe, and in all cases avoid premature digging The florist who forces the bulbs should exercise care in planting. Throw out all injured bulbs, and plant in well-drained, well-aerated soil. Endeavor to keep down aphides and mites from the start, and exercise care in watering and ventilating. Avoid feeding with solutions of horse, cow, and sheep manures, and use chemical fertilizers instead.

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